Analytical Tools and Processes in Land Management Planning

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Dr. Al A. Dyer

PREFACE

This paper describes the "state of the art" of analyses utilized in U.S. Forest Service land management planning. Specific consideration is given to management science, ecological, and economic models of resource management systems. Models used in U.S. Forest Service Planning between 1979 and 1989 are the primary focus of the paper, but an attempt is made to address emerging models and approaches. It is organized into four major sections: the planning process issues related to analytical models used by the Forest Service, a management science perspective of forest planning, ecological analysis and economic efficiency. A fifth section summarizes research needs for land resource management planning. An executive summary is included to summarize the document.

EXECUTIVE SUMMARY

This report summarizes and critiques the models used by the Forest Service in developing the current versions of national forest plans. From this we attempt to synthesize the "state-of-the-art" of information and analysis tools used in National Forest Planning. This synthesis indicates that major technological gains were made in developing information, analysis tools and procedures, and analytical skills. Considerable knowledge of the utility of systems models in natural resource planning was gained. Weaknesses in information, analysis tools and procedures were identified, and incremental improvements which are likely to improve the process given currently defined planning decisions/questions are suggested.

The most important management science issues relating to FORPLAN were:

1. The models became too large and complex. The consequences of this were high costs of model development and excessive computer costs.
2. The data used to develop the models was not good enough. Particular attention has been focused on the response of non-commodity outputs to management actions, the values for all outputs, the information used to predetermine some land allocations such as minimum management requirements (MMR's), the costs of management actions, the specific objective levels stemming from issues-opportunities-

concerns (ICO's) analysis, and the land classification procedures used to identify analysis areas.

3. Management scientists who have commented on FORPLAN almost always point to the FORPLAN system's inability to effectively deal with uncertainty about resource response, prices, costs, and objectives as a shortcoming that should be addressed.
4. The inability to completely resolve management issues stemming from the spatial arrangement of management actions is viewed by many as the single most important shortcoming of FORPLAN. (This part of the critique is located in the ecological section of this report).

But, no other system which sought to integrate the various components of the national forest planning problems was available. Thus, FORPLAN was selected as the best available alternative.

Ecological questions that have been raised in respect to information and analyses used in forest planning can be summarized as follows:

1. By far the most common criticism is that there are many cases where basic ecological responses are not known well enough to make output forecasts needed for planning. Obvious examples include fishery response to harvesting and increased sediment loading of streams; recreation use and quality of experience response to management actions such as timber harvesting, livestock grazing, mining, changes in

recreation facilities; wildlife population response to various management actions; wildlife related recreation response to changes in wildlife populations; and impact of management action on visual quality. But, even timber growth and yield, forage, and water models have been questioned. Models of change in fire hazard stemming from various management regimes were also criticized.

2. Consequences of landscapes and spatial arrangements of management actions are not analyzed correctly.
3. The importance of non-linearities has not been examined.
4. Little has been done to incorporate the consequences of uncertainty into the models.
5. The relationship between ecological analyses and the decision-support tool (FORPLAN) needs to be clarified.

The economic analysis aspects of the Forest planning process involve a variety of issues, from the role that the analysis should play to specific procedural methods. The details of economic analysis in Forest planning have frequently become the focus of discussion by user groups that question the appropriateness of the recommended plan. It often seems that debate about economics is the "handle" stakeholders use to express their dissatisfaction with proposed actions. Specific criticisms included,

1. <u>The Role of Economic Efficiency in Forest Planning.</u>
The National Forest Management Act (NFMA) regulations and various other Forest Service rules and directives implied that some type of benefit-cost analysis (present value, cost-effectiveness, cost-efficiency) is required in Forest planning. For example, some assert that the NFMA is a mandate to manage the Forests as economic "assets". Also, some administrative policy statements strongly support the use of benefit-cost analysis. Others assert that, while important, economic analysis is simply one of many information sources to be used in assembling plans. The basic issue seems to involve "too little emphasis" versus "too much emphasis" on economic efficiency as a principle of Forest planning.

2. <u>FORPLAN as a Model Structure for Economic Analysis.</u>
FORPLAN is an implementation of constrained optimization which allows the application of virtually any combination of priced and non-priced constraints to the analysis. Some argue that most FORPLAN models are large, cumbersome, expensive, and filled with "imperfect" data and "artificial" precision and counter that smaller, less "precise" models would be advantageous. A basic issue seems to involve the relative merits of using large, complex models versus smaller less rigorous models to perform economic analysis for Forest planning. Even the

appropriateness of doing economic analysis within FORPLAN has been questioned.

3. FORPLAN as a Tool for Economic Analysis.

   FORPLAN models were large, expensive to construct and solve, complex and often difficult to understand. It has been suggested that broad and rigorous economic analyses were not completed because of these characteristics. It is argued that equivalent or even more useful economic analysis could be accomplished outside of the FORPLAN structure.

4. Demand Analysis in Forest Plans.

   The concept of demand as a price-quantity relationship is a basic tenet of economics. It was not possible to define demand rigorously for even the priced outputs addressed in Forest planning. However, it is intuitive that, at some point, all outputs have a diminishing marginal value (or even zero or negative value).

5. Benefit Values.

   Unless approved to do otherwise, forests were directed to use Resources Planning Act (RPA) benefit values. Some Forest plans used 1980 values while others used 1985 values. There is great variation of opinion about whether or not the recreation, water, or range values are too high or too low. Similarly, the issue of real price increases was not entirely resolved.

6. Supply and Cost.

Cost relationships were almost always average (instead of marginal) and were frequently determined for the Forest as a whole rather than some smaller unit. Costs were usually estimated from historical records and may not reflect what was actually spent. Distinctions between fixed and variable costs of management prescriptions were typically not clear.

7. Lands Suitable for Timber Production.

In the development of the NFMA Regulations, the identification of suitable timberlands was noted as a particularly complex and controversial issue. Both the procedural and policy aspects of the issue remain a subject of debate. Disagreement remains over the process of classifying timberlands as suitable or unsuitable.

Improvement of analytical tools and processes in land management is probably an expectation of most people who read this paper. General areas in national forest planning needing investigation include,

- improvement of present analytical tools and processes
- different planning approaches
- linkages and interactions in the planning problem
- risk and uncertainty.

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PLANNING PROCESS ISSUES RELATED TO ANALYTICAL MODELS

Allen and Gould (1986) suggest that strategic planning of public forest lands is a problem that cannot be solved with systems analysis, and that trying to do so can be a "wicked" experience. Nadler (1980) states that using a systems approach to solving large public planning problems is usually accepted as the approach to use. He continues by saying that the unstated assumption that this approach must be used "now loom as the problem and may be the biggest stumbling blocks to finding the good solutions society needs. Both papers capture the sentiments of many participants in forest planning.

The planning process implemented within the context of the Resource Planning Act (RPA[1]) and National Forest Management Act (NFMA[2]) and the specific role planning analysis played in this process are key determinants of "how well the analysis was done" and therefore how adequate the models were. Cortner and Schweitzer (1983b) describe the RPA/NFMA as "the most complete statement of a fully rationalistic planning process". In their view, the diversity of values competing to facilitate the analysis and influence the results makes forest planning fundamentally a political process that defines winners and losers rather than simply a technical enterprise to define truth. They

[1] The Resources Planning Act, passed in 1974, attempts to balance industry needs with the environment. Dana and Fairfax (1980 p324) state the RPA directs the Forest Service to assess resource needs and capabilities, define alternatives, and recommend a program of management and investment as a basis for its budget requests".

[2] The National Forest Management Act was passed in 1976 and made substantial additions to the RPA.

cautioned that insufficient awareness of the political aspect of planning and the constraints it imposes on the analysis and expected results will lead to a failure of the planning process. The major issue is, did the analytical models serve the process described by Cortner and Schweitzer?

The Forest Service Washington Office expected the analytical models to address:

- Multiple use goals and objectives
- Forest wide management requirements (standards and guidelines)
- Management Areas and management area direction
- Determination of allowable sale quantity
- Non-wilderness allocations or wilderness recommendations
- Establishment of monitoring and evaluation requirements
- Project and activity level decisions.

To these general requirements can be added Mitchell's (1986) major requirements for analysis:

- Analysis should identify the full range of realistic production possibilities on the forest through benchmark[3] analysis.
- Alternatives should collectively address all major issues and concerns facing management of the forest including meeting management requirements of 36 CFR 219.27[4].
- Alternatives should be implementable.
- Analysis should include a full range of management prescriptions for each type of land on the forest.

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[3] Benchmark analysis involves defining the feasible alternatives through several model runs. For example benchmarks defining feasible timber harvest alternatives might include a maximum timber benchmark and a maximum wilderness benchmark (see Johnson et al. 1986 p.2-6).

[4] Code of Federal Regulations. Title 36, Part 219, Section 27.

- Prescriptions should be the most cost efficient to meet goals and objectives.
- Standards included to meet minimum management requirements (MMR)[5], goals and objectives should be the most cost efficient set of standards.
- Analysis should include analysis of opportunity costs for meeting minimum management requirements.
- Timber analysis should address a full range of rotation ages including harvest before culmination of mean annual increment, biological maximum timber production, departures from even flow, opportunity costs associated with multiple-use and dispersion considerations, and realistic harvest levels including considerations for transportation networks and dispersion of harvests.

To achieve these objectives, the Forest Service Washington office directed that FORPLAN become the centerpiece model for carrying out this analysis (USDA Forest Service 1979). FORPLAN is a linear programming (LP) model which has been augmented with data input programs and output programs which produce reports from the data and LP analysis. FORPLAN maximizes a objective function subject to a set of constraints.

There are two basic harvest scheduling formulations incorporated into FORPLAN, model I and model II. A simple example of model I follows:

Assumption for Model I: an area is assigned to a prescription[6] remains assigned to the same prescription throughout the period covered by the plans.

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[5] "The minimum specific management requirement to be met in accomplishing goals and objectives for the National Forest System." (36 CFR 219.27) For example, the harvest free acres needed to stabilize a fragile watershed.

[6] a prescription is the schedule of activities on an area of land.

The objective function maximizes present net value:

$$Max\ Z - \sum p_{ij} * x_{ij}$$

Subject to:
acreage constraints,

$$\sum x_{ij} - RHS$$

output constraints, and minimum management requirements,

$$\sum a_k * x_{ij} - RHS_2$$

where:

p_{ij} - the net present value of x_{ij}.
x_{ij} - area regenerated in period i and harvested by prescription j.
a_k - coefficients
RHS - the right hand side value of constraints

Model II is different from model I in that the initial prescription may be changed to a different prescription during the planning horizon. An example of model II can be seen in Dykstra (1984 p130).

Forplan version 1 was based on a model II formulation. It was widely used in forest service planning, however, it was a strata-based model[7] and had drawbacks. Johnson et al. (1986 p4-18) lists the drawbacks associated with a strata based approach;

1) the spatial feasibility of the set of actions associated with linear programming solution may be difficult to assess.

[7] Strata based models define the decision variables based on strata or land/resource characteristics. For example, the variable definition usually includes mention of the period and prescription i.e. x_{ij} - area regenerated in period i and harvested by prescription j.

2) the necessity of putting all yields on a per-unit-area basis may lead to these yields being incorrectly represented in the problem.

These drawbacks evoked the development of other approaches. In some cases area-based models[8] were used instead. This lead to the inclusion of area-based and strata-area based model capability into FORPLAN and was called FORPLAN version 2[9].

What was expected of FORPLAN? Iverson (1986) says:

> The revolutionary aspect is found in the expectation of both model developers and users that one model could be used in an interdisciplinary manner to process information. This would provide a "level" playing surface such that all members of an interdisciplinary team would have equal access to the model. That is, the central focus of analysis concerns germane to the problem at hand rather than having the focus to be determined by the group that developed and/or maintained the model (p.23).

Barber (1986) adds:

> Planners want to remove themselves from the influence of timber and also from the simplistic mapping overlaying mysticism of Ian McHarg and the architect planners. Therefore, everything had to be quantified and modeled in FORPLAN (p. 88f).

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[8] Area based models define decision variables based on the allocation and scheduling choices for each different area. For example a decision variable could be defined as the portion of an area assigned to a timing choice and a allocation choice. See Johnson et al. (1986 p4-25)

[9] FORPLAN version 2 is used in the rest of the paper unless stated otherwise.

Hierarchial Planning Issues

The relationship between national, regional, and forest level goals and objectives has been the subject of comment throughout the NFMA planning experience. Despite criticism related to imposition of national objectives on forests by some (particularly timber-related objectives) within the Forest Service, there has been consistent commitment to the linkages between RPA and annual program planning and the forest planning process. The recognition of important relationships between forests in a region and all forests spawned significant discussion of hierarchical planning systems and models.

The Office of Technology Assessment (1991) found that national targets can nullify local decisions and had two suggestions:

1) specify forest plans as the baseline for RPA planning

2) require RPA direction for all resources and all branches

Schweitzer (1983) says:

> National goals to produce timber and to provide opportunities for outdoor recreation and other outputs are defined through national planning that is conducted every five years; tentative "shares" of output targets are assigned to each forest for consideration in local forest planning as management concerns...Commodity interests are likely to argue that too much emphasis is being placed on preserving current conditions or on protecting the environment. Others argue that there is an over-emphasis on meeting targets, which are most clearly specified for commodity outputs (p.3).

Hof(1987) reaffirms that linkages between levels of planning is necessary for FORPLAN to be effective. He states the linkage between RPA planning and forest planning might best be developed

through a game theoretic approach such as that discussed by Kornai and Liptac (1965). Dykstra (1987) in a responding paper agrees with Bare and Field's (1987) conclusions on the need for hierarchical approaches, but feels that "their recommendations (as strong as they are) don't go far enough". He proposes a three level planning system with strategic planning (allocation) being conducted at the national level, tactical planning (scheduling) being conducted at the forest level, and operational planning (implementation) being conducted at the district level. Navon (1987) also supports the idea of these hierarchical approaches and thinks the simplification of the models is the best plan of attack. Weintraub and Cholaky (1991) follow Paredes (1988) in supporting and analyzing a two level strategic-tactical approach, further they use a test case to show the feasibility of their approach.

Results of a survey completed by Hoekstra et al. (1989) include:

> - One respondent observed that the Regional Forester is the designated deciding officer, but all the analysis and coordination is done at the forest level. Current approval process probably provides consistency in plans and programs, but may lead to lack of ownership on the forest, particularly when the Regional Forester has changed the Record of Decision (ROD)[10] from the recommendation by the Forest Supervisor. Such a decision process could also jeopardize public participation efforts.
> - Several respondents cited the Forest Service organizational structure as a deterrent to integration. They observed that the concept of integration seemed to diminish in higher levels of the agency.

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[10] A record of decision is a written document that records the reasons, environmental consequences and public involvement of a Forest Service decision. It is required by NEPA.

- The agency has never clearly defined the role of forest planning in the overall agency planning process (i.e., RPA, strategic, tactical, and operational or project level planning).
- The planning problems and issues have not been clearly defined or understood by those doing the forest planning job.
- There was inadequate involvement with and ownership of forest plans by district personnel.
- Develop the policy statements and direction necessary to clearly define the relative roles of each level of planning, the relationships between them, and the decisions to be made in each.
- Develop an understanding of district level decision maker information needs and build both these needs and district level involvement into the forest planning and analysis process.
- Aggregate data and analysis from the district level up in order to insure that districts are properly involved in forest planning.
- There was a lack of commitment to forest planning and to the utilization of the results of the analysis for "on-the-ground" management.

Throughout the planning-budgeting process of the 80's, separation of the annual program planning and budgeting process from the strategic planning process resulted in vague implementation of strategic planning results. The problems caused by the separation were widely discussed both within and outside of the Forest Service. A result of these discussions is a meaningful effort to establish effective linkages between the annual program planning and budgeting and strategic planning results. Future reviews will reveal the success or failure of agency attempts to solve this problem.

Site Specific Versus Strategic General Planning

Many of the criticisms by commentators cited in subsequent sections of this report, particularly in the critique of economic

models, appear to be based on the assumption that the NFMA planning process is designed to produce site specific project proposals. To the contrary, Gippert (1989) says:

> The LRMP[11] management area and forest-wide direction are the "ordinance" under which future decisions are made. Forest Plan approval establishes multiple-use goals (desired future condition) and objectives (statements of planned results) for the planning unit. Coupled with the laws and regulations applicable to LRMP implementation, the plans create a dynamic, two step management system for future decision making...Somewhat like a zoning ordinance, the LRMP allows or prohibits some uses and establishes standards and guidelines which regulate resource use.

This opinion, from legal staff, is a strong assertion that site specific project recommendations should never be the outcome of NFMA planning. Troyer (1986) makes the same point in commenting on the Integrated Resource Management process as a contrast to FORPLAN.

> This process recognizes that the plan itself does not provide enough site-specific information for district rangers to begin plan implementation (p. 121).

Similarly, comments from the U.S.D.A., Forest Service Administrative Appeal Decision, (USDA, Forest Service 1988) say that the Marvel appeal of the Toiyabe National Forest LRMP...

> incorporates legal mandates, professional judgment, and the public's stated concerns into a future vision of the Forest...LRMPs do not apply direction in site-specific management activities. It would be unrealistic and wrong to try to identify, analyze, and schedule the myriad of projects or activities that occur on a National Forest. Instead, this type of site specific planning occurs at the project level planning stage, such as allotment management planning (p. 3).

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[11] A land and resource management plan (LRMP) is required by the NFMA. It is also called a land management plan or a forest plan.

Finally, from the USDA, Forest Service (1988) in a description of the Burnett appeal of the Rio Grande National Forest LRMP:

> For individual timber sales, in contrast, economic analysis is conducted in the sale planning process at the time the decision to offer a sale is made. No final decision about an individual sale is made in the LRMP, and no economic analysis of individual sales is required in order to approve the LRMP (p. 6).

Barber (1986) offers a troubling perspective about the appropriateness of FORPLAN for accomplishing these strategic objectives.

> Many problems in LRMP lend themselves to FORPLAN analysis; however, most are tactical (determining what task to do) rather than strategic (determining what we should do). Finding the most efficient schedule of treatment for a particular class of land is a reasonable problem for FORPLAN. However, such an analysis is only relevant after a decision has been made that such treatments are appropriate and desirable for that land. Experience has shown that these problems are not solvable by FORPLAN and are usually solved politically by selecting that solution which has the "least resistance" or is the "most emotionally satisfying" to the decision maker. There are no correct solutions, only more or less desirable ones (p.89o).

The responses from Barber (1986) and Cortner and Schweitzer (1983b) have a similar thread. Both indicate forest planning is a combination of FORPLAN analysis and politics, with FORPLAN analysis working within the boundaries set by political processes.

Hoekstra et al. (1989) note that section 219.4 of the regulations (Planning levels) does not relate to decisions needed to implement forest plans--another decision level. This has probably contributed to the confusion of what decisions are being

made in the forest plans and how site-specific they need to be.

They say:

- Many of the responses raised the issue of site-specificity of decisions and analysis:
- There appears to be confusion as to what level of specificity is required for a programmatic EIS (i.e., how closely can it be tied to the ground?).
- The confusion over the site-specificity of the forest plan analysis and decision was stated as being both internal and with our publics.
- The activity schedule requirements of 219.11(c) include "proposed and probably management practices such as the planned timber sale program." Such wording has often been interpreted to mean site-specific requirements.
- Many units indicated there was not a clear understanding or depiction of what decisions were being made in forest plans and what decisions would come during implementation. Recent appeal decisions have clarified this somewhat, but further clarification is needed.
- The apparent confusion over the scope of the forest plan could be the result of lack of understanding of the difference between a programmatic and strategic EIS.
- Many of those concerned about the adequacy of their timber resource land suitability analysis were also concerned about the site-specificity of the forest plan analysis and decision in general. This could mean that the inability to determine the location of land suited or unsuited for timber production was related to their general concern about site-specificity. Without the need for site-specific location of suited or unsuited lands, the models and data may not have been limiting.
- While the regulations do not require site-specific display of timber sale information, Forest Service direction requires it (Washington office memo to forests). This appears to be inconsistent with the nature of a programmatic EIS which does not contain site-specific analysis.
- Implementation problems have emerged due to: a lack of spatial analysis due to limitations in FORPLAN and poor understanding of the relationships between forest and project planning.

FORPLAN evolved throughout the 80's in ways that helped address issues related to site specificity and spatial arrangement of land allocation and activities. But, improvements achieved in this period did not fully solve the problems, and attempts to deal effectively with these issues continues. As

noted above, recent efforts to address spatial questions have focused on direct linkage of plan implementation and program planning to strategic planning. Additionally, some analysts seek to solve the technical and analysis problems by implementing geographic information systems (GIS) techniques in concert with linear programming.

Miscellaneous Planning Process Questions Related to Analytical Techniques

Other planning process-related issues which raise additional questions about the ability of the models and analyses to accomplish what was needed. For example, Bare and Field (1987) suggest that there was no clear understanding of the relationship between analysis and decision making. They do conclude that FORPLAN provided a useful accounting tool and that in some cases it provided novel and defensible recommendations. Barber and Rodman (1990) concurred in lack of understanding between analysis and decision making in stating:

> most decisions on forest planning are made in response to crisis problems-old growth, preservation, herbicides, below-cost timber sales, etc. rather than Forest Service goals, vision or mission statements. (p.28)

In commenting on the capability of modeling a Forest planning/decision problem, Troyer (1986) says:

> There were 16 decision criteria used in our Forest plan. These decision criteria, as much as possible, were

> reflected in the model as constraints. It was difficult at best to fully reflect these criteria mathematically (p. 117). In a statement which appears to reflect significant frustration he says, "we can not afford sophisticated analysis that does not really change our decisions" (p. 118).

In a sharp characterization of what was actually done to keep FORPLAN from producing unacceptable plans, Barber (1986) says:

> FORPLAN produces reasonable results because its builders impose constraints that prevented it from producing anything else (p.89f).

While the types of adjustments described by Barber are a normal part of developing and using a complex systems model such as FORPLAN, Barber seems to be suggesting that the model or the analysts were fundamentally incapable of addressing the analytical problem associated with developing a Forest plan.

Barber and Rodman (1990) expanded the above idea stating:

> The model often ended up in the wrong hands, solving the wrong problems, for the wrong reasons, and thus led to great disappointment in the results. It provided analysis which did not analyze, provided the right answers to the wrong problems, and provided complication rather than comprehension (p.27).

Budgets have a direct affect on forest plans. Hoekstra et al. (1989) cited the lack of budget considerations in planning, saying;

> A stronger link between planning and the budget process is needed. The forest planning analysis should explore the sensitivity of the plan to different budget levels (p.14).

Budget decisions can overwhelm planning decisions (Office of Technology Assessment 1991). They state budget requests and appropriations from congress are not consistent with budget levels assumed in forest planning.

Incorporation of Goals, Objectives, and Constraints into Analytical Techniques

General Goals and Objective Process

Within the NFMA planning process as implemented in FORPLAN, no single action affected the optimal solution more than output and/or management area goals imposed on the FORPLAN model. For example, setting timber output objectives at, near, or above a forest's basic biological potential mutes the need for analyzing opportunities to produce other outputs on land capable and needed to meet the timber objective. Other outputs will be produced on these lands, but only in connection with the timber program. In general, objectives imposed on FORPLAN are related to the Issues-Concerns-Opportunities (ICO's) analysis. However, the imposition of national goals often makes direct linkages of specific output objectives to the ICO's difficult or impossible. The "soft" nature of ICO's also makes it very difficult to translate them into quantitative objectives which can be incorporated into FORPLAN. Many ICO's must be handled as "area constraints" and may be described as Minimum Management Requirements to achieve, for example, threatened and endangered species goals. The

complexity of this process ensured that there would be substantial criticism by user groups that felt their particular objectives were not being met. For example Baltic et al. (1989) quote from the National Forest Product Association's view:

> - The procedures for setting management objectives and making decisions are confusing, unclear, and too broadly defined;
> - The public participation process is unclear and subject to abuse--opportunities for public review and comment on the intermediate planning steps and on policies formulated at the national office level are not made available or are ignored (p.4).

In describing how constraints related to specific output objectives or area management affect the set of management prescriptions selected as optimal, Walker (1983) asserts that:

> the Forest Service planning process is seriously flawed because the economic efficiency objective that Congressional intent clearly called for has, in fact, been replaced by an irrational imposition of certain traditional Forest Service management constraints.

Analysts and planners recognized the importance and difficulty of incorporating goals and objectives into a planning analysis based in FORPLAN.

> The primary problems and issues on the White River were resolved through intensive public involvement. The only substantive appeal involved a wilderness prescription. The use of FORPLAN was not an issue nor were any of our analysis techniques (Troyer 1986).

Minimum Management Requirements and Goals and Objectives

In some cases the constraints associated with minimum management requirements (MMR's) became the focus of criticism on

the way goals and objectives were incorporated into FORPLAN. In the Northwest Forest Resource Council (1987), appeal of the Siuslaw LRMP they assert that the Forest Service should not use MMR's in a Forest Plan until public participation and rule making for MMR's is completed as required by NFMA and NEPA. They raised concerns about the validity of the sedimentation model.
In the Associated Oregon Loggers Inc. (1987) appeal of Siuslaw they claimed that the construction and implementation of the MMR's was done without adequate public review and input.

O'Riordan and Horngren (1987) claim that the Minimum Management Requirements violate the NFMA. They charge that the Forest Service considers the MMR's as...

> inflexible legal standards over which there is no discretion and that the agency applies them as a common constraint across all forest plans and alternatives.

Hoekstra et al. 1989 stated minimum management requirements were useful for:

(1) providing a consistent interpretation of legal requirements.
(2) facilitating tradeoff analyses and model validation.
(3) defining the forest planning decision space.

In commenting on even flow constraints Kent (1989) notes:

> One of the more important features of forest planning analysis to date has been the incorporation of constraints designed to ensure that temporal equity conditions are met for specific outputs. The most important manifestation of this has been in the almost universal use of non-declining yield constraints on timber harvest in FORPLAN models. The concept of even flow

applied to other outputs has also meant conservation for such things as forage, and thermal/hiding cover for wildlife.

The effect of these "even flow" constraints on optimal solutions is significant. As an example, McQuillan (1986) suggests that under certain conditions, these constraints can cause decreasing harvest levels as a result of planning reanalysis every 10 years. It is generally recognized (Clawson 1977) that these constraints affect harvest patterns and cause a significant reduction in optimal present net value. Pickens et al. (1990) found that decreasing harvest levels do occur but the impact is lessened by certain factors.

There can be no doubt that MMR's were reflections of ICO's which affected plans significantly. In some cases they could be called the key land use decisions which resulted from the planning process.

Community Stability Constraints

Much of the history of even flow constraints is rooted in concerns for community stability. Even flow constraints were among the most important components of FORPLAN. Additional constraints were often added to represent objectives of the alternative such as maintaining at least a level of timber harvest that would maintain local dependent industry (Wilson 1986, p. 59). Criticism of these constraints develops when they result in a timber program that impacts other outputs such as recreation and visual quality. In some cases these constraints

lead to "below cost timber sales" and stimulate criticism based on economic logic. In response to these criticisms, the USDA Forest Service (1988) says:

> In response to the appeals of the San Juan and Grand Mesa, Uncompahgre, Gunnison National Forest plans, it is noted that since there is no indication in the planning documents that increases in timber sales will be made only if there is an increase in demand and prices for timber, an explanation is needed as to why increasing the dependency of local community mill capacity and jobs which could result from an increase in sales of National Forest timber with revenues exceeding costs will contribute to greater national or local welfare-- especially since increased dependency upon submarginal timber sales would seem to result in potentially greater community instability due to uncertainties over continuation of relatively high level of Federal funding to support a timber program with costs greater than revenues (p. 2).

Similarly, Schallau and Alston (1987) note that community stability should not be used to justify high levels of timber sales that cannot be justified for biological or economic reasons.

A MANAGEMENT SCIENCE PERSPECTIVE OF FOREST PLANNING

General Comments

Many questions have been raised by analysts, researchers, user groups, and forest managers about the efficacy of FORPLAN as the cornerstone National Forest planning tool. The most important issues include model size and complexity, quality of data, limitations of linear programming, and spatial issues (discussed in the ecological section of this report). These issues, among others, led Iverson (1986) to comment:

> Suffice it here to note that the system was not universally accepted as "the" forest planning model, regardless of a Forest Service decree to that effect (p.23).

These comments aside, there is much agreement that FORPLAN was the best tool available when the forest planning process was initiated. Teeguarden (1987) noted that some type of mathematical model was needed to address questions posed in the regulations. Iverson and Alston (1986) assert that FORPLAN was the best candidate available, and Sessions (1987) voiced what appeared to be the general sentiment of a 1986 Symposium organized to evaluate FORPLAN when he said:

> Concerning improving the planning process, there was general agreement that FORPLAN met the analytical requirements of the National Forest Management Act (NFMA)...I must conclude there is general agreement that FORPLAN has made a significant contribution to forest planning. The economists, the ecologists, and the managers here have largely been satisfied by the ability of FORPLAN to adequately represent their concerns and address issues at the forest level (p.163).

Binkley (1987 p. 207) describes key problems in a general way when he identifies six costs of utilizing FORPLAN: analysis costs, institutional costs, increased centralization, increased ignorance (loss of understanding through complexity), planning in a vacuum (the losses from focusing on individual national forests without consideration of adjacent lands), and implementation. However, he notes that FORPLAN is partially effective in determining economically efficient solutions, but he also suggests that if simulation is the goal, FORPLAN was probably a poor choice. Given these concerns, one might ask why was FORPLAN selected as the center piece of Forest Service Land Resource Management Planning? Iverson and Alston (1986) say that...

> computerized LP models have thus become popular not because the models make decisions, but because they can facilitate better decisions by evaluating several hundred thousand decisions variables in a fraction of the time it would take to locate the best combination of decision variables by hand (p.10).

It is interesting to hear the perspective of an analyst that used FORPLAN as an aid in developing a Forest plan.

> The problem of coefficient estimation is often compounded for many economic parameters due to the complexity of the interrelationships involved...To arrive at the contribution to the objective function for big game hunting benefits requires estimating several interrelated, cause-and-effect relationships in addition to the separate estimation of the per unit benefit value of big game hunting....A common reaction to data problems and inability to specify production functions is to adjust the role that FORPLAN plays in the planning process. FORPLAN has been used as a simulation/optimization model rather than as a pure optimization model..."Preallocation", as the procedure outlined above is often termed, has significant implications in terms maximizing economic efficiency (Wilson 1986, pp. 63-64).

This observation suggests that FORPLAN was not used as a "pure" optimization tool, that many decisions were made outside of it, and that repeated trials with the model were necessary to identify prescription sets that managers and analysts felt addressed the ICO's for each alternative plan. These observations are rich with insight into the utility of a model such as FORPLAN and how the model was used, given the shortcomings inherent within it.

Iverson (1986) offers validation of this approach and recites the perspective of management science:

> Mathematical programming in general, and linear programming in particular, is most useful as an aid in understanding the nature of the problem, not in providing a set of numbers representing the "answer" to a problem.

Geoffrion (1976) instructs...

> that the true purpose of mathematical programming is: to help develop insights into system behavior which in turn can be used to guide the development of effective plans and decisions. Such insights are seldom evident from the output of an optimization run. One must know not only what the optimal solution is for a given set of input data, but also why...The desired insights usually have more to do with "why" than the "what".

However, both users and critics found that problems remained.

> "While FORPLAN has permitted modeling many different resources, it has not been able to adequately respond to several emerging issues in Forest Planning. Four of these issues are the economic appropriateness of timber management, the interactions of wildlife in response to changing vegetative conditions, the spatial and temporal distribution of timber harvests, and the actual role of analysis in Forest Planning and implementation...Neither version did a very good job of addressing the below cost sales issues" (Connelly 1986, p.97).

As noted in the process section, a number of commentators have raised strong objections to the way forests incorporated constraints on the FORPLAN model. Specific concern has been expressed about MMR's. The questions raised by Hamilton (1987) in regards to headwall leave area MMR's described in the Siuslaw National Forest plan are perhaps as good an example as any. Hamilton makes the point that the rationale and/or science used in identifying the number of acres needed for headwall protection and the location of these acres is not explained. He asserts that there is a strong possibility that these MMR's were arbitrarily determined and located.

Similarly, O'Toole (1986) raises questions about timber output targets that result from higher level planning (national and regional). He asserts that these constraints in FORPLAN can result in sub-optimal plans that emphasize timber management at the expense of other outputs such as wildlife and recreation.

A side issue which has been raised is the relationship of FORPLAN to other land management analysis techniques, particularly geographic information systems. Dellert (1987) notes that...

> FORPLAN would be a more attractive system if it could be simplified and easily linked to other planning systems such as a geographic information system (GIS) (p. 206).

It can be noted that the Bidger-Teton National Forest has used geographic information systems extensively in the development of its plan. In addition, research and development work on

FORPLAN/GIS jointly conducted by Region 3 and Northern Arizona University is building on this concept.

Model Complexity and Size

A common criticism of FORPLAN relates to the size and complexity of the models. The consequences of large size and model complexity were high planning costs and an inability to understand the results of the model. In addition, many have suggested that the large size and complexity made it impossible for some analysts to develop models that adequately reflected the planning realities of their forest. A result that flowed from this was plans which could not be implemented because the plans described situations that simply did not exist on the ground. Where this happened, one must surmise that the analyst, ID team, and forest managers forgot the purpose of management science and FORPLAN, a tool to provide information--not to define the "plan".

Examples of comments on size and complexity include those of Iverson and Alston (1986) who say that the major accomplishment of FORPLAN Version 1 is its ability to trace multiple resource activities through time. However, they discuss problems with respect to model size and the generation of unreasonable timing choices...

> problems include model size and difficultly in generating spatially reasonable land allocations and activity schedules (p.16).

As an example of what the size/complexity issue involves, consider the Tahoe National Forest. The Tahoe uses the FORPLAN model Version 1 with an average matrix size of 2,500 rows and 28,000 columns. The model had 204 analysis areas which were formed from 26,000 capability areas (West 1986).

As part of the strategy to deal with size and other problems, coordinated schedules[12] were developed. Iverson and Alston (1986) noted that coordinated schedules were developed by an interdisciplinary team and were associated with single decision variables in the model...Model sized decreased.

The perspective of some user groups, however, remains that because of size and complexity, FORPLAN and the entire planning process was not appropriate. For example, Baltic et al. (1989) says that The Northwest Forest Products Association (NFPA) believes...

> that the analytical planning procedures are too complex, expensive, and time-consuming and the data base utilized is of questionable validity (p.4).

Another perspective on model size which suggests how analysts addressed size problems is offered by Wilson (1986):

> Another reaction to data problems is to limit the size and complexity of the model...The simpler model may appear less complete, but may be more useful if it is easier to interpret and there is a higher level of confidence in its coefficients (p.64).

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[12] "A coordinated schedule is an activity column specifying all the production relationships for a zone of land. The activity column specifies both location and timing for all activities, outputs, costs and benefits from the present planning horizon." (Iverson and Alston 1988 p30).

This is a suggestion that in some cases FORPLAN models were restricted because data were not available to model some important relationships. While this may have occurred in special circumstances, the overwhelming sense is that the models were too large and complex to be useful planning tools.

Naturally, numerous commentators stress the need for simpler more understandable models.(e.g. Barber 1986. Greer 1986. Voytas 1986). Barber (1986) says:

> Smaller models also would facilitate translating FORPLAN solutions into projects since managers would have more discretion in selecting acreage to correspond with the FORPLAN schedule rather than searching for something which may not exist (p.89m). He continues in saying large models are justified if:
>
> 1) there were going to be a close adherence between the FORPLAN schedules and allocation of activities and on the ground projects,
> 2) the error inherent in the input data were greatly reduced,
> 3) the problem to be solved were well defined,
> 4) the analyst were familiar with the theory and methodology or the production functions and constraints and had the knowledge of why and how activities are actually accomplished. (p.89L)

Barber (1986) says, While analysts are aware that every decision does not have to be made today, they design their matrices as though this were the case. Large models have just as much detail in the last period of the planning horizon as in the first. He asserts that:

- There is often an inverse relationship between model size and forest complexity
- There number of errors and erroneous interpretations of results increases by the square of model size

- There is often no correlation between the level of detail in the management direction and the level of detail in the matrix
- In 10 forest FORPLAN formulations, 10% of the variables account for 80% of the solution. (p.89b)

In expanding on why the models became so large, he offers the following observations:

- We must quantify as much of the problem as possible otherwise we will not have as objective or comprehensive an analysis as required by the National Forest Management Act.
- The greater the number of activities, constraints, and outputs, the more accurate and better the solution will be.
- Large models that allow the specialists their inputs will make the model more transparent to them and generate greater ownership in the FORPLAN analysis.
- Even if scientific information is lacking, "professional judgement" can fill in the gaps.
- Large models are necessary so that we can quantify as much of the problems as possible.
- Large models are needed so we can disaggregate the solution to site specific locations rather than having forest-wide averages. (p.89f)

These are the kinds of issues that drove analysts and the ID teams to "enhance" their models. They remain key premises of the LRMP planning process. If they continue leading to large complex models which cannot be interpreted, the FORPLAN process will have to be revised.

Many respondents to the <u>Hoekstra et al. (1989)</u> surveys said that they could have done a much better job of developing a broad range of alternatives. Most of those respondents cited a lack of time as one of the reasons why more sensitivity analysis was not conducted. As a result, usually only the benchmarks and alternatives required in 219.12(f) and (g) were analyzed in addition to the final set of alternatives for the EIS. These

requirements may have promoted a broader range of analysis than would have been conducted otherwise, but they may have also narrowed the analysis by not focusing the analysis on the issues.

Poor Data

Krutilla and Bowes (1989) summarize what data is needed and why it is poor when they state:

> The information required in forest planning is the change in a forest resource in response to an incremental change in management inputs. Because this kind of information is very difficult to obtain, there has been substantial uncertainty concerning the value of biophysical responses to changes in management activities (p.746).

Leonard (1986) describes the process analysts necessarily used in developing data to support the models.

> You discovered some innovative ways to overcome shortages of data, particularly with respect to the wildlife and watershed functions. Often you used a series of proxies to represent these resources; that is, you found ways to constrain the model to ensure desirable distributions of vegetation or to regulate the amount of cutting in a drainage. Such approaches were useful in making the model work, but they relied on an "overlay approach" rather than on the optimization capabilities of the FORPLAN model. Rather than reflecting the integration of resources, these techniques simply apply absolute constraints on timber harvesting. We need to find better ways to include non-priced resources in the FORPLAN model rather than setting them up as constraints on commodity outputs (p. 2).

Given that there was seldom a choice to do anything different from the process Leonard describes, Greer (1986) and Wilson (1986) both note that the poor data included in FORPLAN models

necessitates extensive sensitivity analysis to verify results. But they note that this process may be prohibitively expensive with large models such as those generated in using FORPLAN.

Barber and Rodman (1990) reinforce the above comments by saying;

> The only problems FORPLAN can solve are those in which both data and data relationships are known. Since there are few data on many forest resources, the model did not find many "real" solutions. Indeed, in most cases, modeling coefficients were based on anecdotal or "best-guess" information rather than scientific quantification (p.27).

Data problems occurred in connection with attempts to develop response coefficients for outputs, prices and values for outputs, costs of management prescriptions, and objective levels. The issues surrounding output response coefficients are more fully discussed in the next section of this report dealing with ecological models. Issues involving prices, values, and costs are discussed in the section on economics, and issues involving how objective levels are handled in the section on the planning process incorporated into FORPLAN.

Most Hoekstra et al. survey respondents cited problems with inventory data and information collection: (1) Inventories often became outdated during the protracted planning process. (2) Existing inventories were not adequate for many resources and new inventories were not conducted. (3) There was often variable quality across the forest (e.g. incomplete data for some areas). Other respondent comments included,

- implementation problems have emerged due to utilization of poor data in FORPLAN

- The quality of the resource data used was often poor and outdated. In some cases, inventory data was non-existent for resources for which the planning process had identified significant issues.
- In some cases, the best available data relative to specific resource issues was not used due to the lack of coordination with the research community.
- There was a prolonged time-lag between data collection and the final forest plan (especially implementation). This resulted in planning analysis which didn't match conditions on the ground.
- On several forests, the management of forest plan information (i.e., documentation, computer files, planning records, etc.) has been inadequate and vital information has been lost.

Limitations of Linear Programming

Bare and Field (1987) discuss five assumptions/limitations of linear programming that apply to FORPLAN: linearity, additivity, divisibility, certainty, and single criterion of optimality. They point out that linearity itself can be overcome with careful model formulation. Additivity and divisibility, however, are more difficult to deal with. Additivity implies that there can be no interactions between decision variables. Spatial concerns are a good example of how this assumption breaks down in forest planning applications. The divisibility assumption relates to the continuous nature of the decision variables. Unfortunately most forest planning problems are mixed integer problems...They say that careful formulation and solution interpretation may at least partially resolve these problems.

It is important to note that Bare and Field (1987) conclude that the most serious problems--model understandability, analysis

costs, and lack of resources to conduct sensitivity analyses--all arise from the formulation of models that are too large.

Perhaps the most damaging comment is the assertion that forest managers and even members of the ID team were left out of the model development process. This is a gross violation of the principles of effective management science. Troyer (1986) says:

> Regardless of the reasons, some forest and district people were left in the dust, so to speak. They were unwilling or unable or not permitted to keep up with the planning process...This barrier is the tremendous informational and understanding gap between the technical experts represented by most of you in this room, and the forest managers represented by me and a few other here...However, I know that this FORPLAN gap must be narrowed considerably if we are to implement Forest Plans successfully...There are those individuals that have no confidence or faith in any of the FORPLAN solutions at all...Those individuals who don't share this lack of faith, share an almost opposite viewpoint. They have blind faith in the analysis.

The expectations of many planners, analysts and line officers were often unrealistic. The limitations both of linear programming and FORPLAN were often not understood, and there was excessive "blind faith" in the results of the analysis (Hoekstra et al. 1989).

Management Science: State of the Art

FORPLAN, through all of it's drawbacks, has significantly contributed to the understanding of forest planning, and that is the goal of management science. The next round of planning should build on all the experience of the first round.

Other management science approaches should be explored on a small scale to see if they can contribute to forest planning. An example might be to change the economic objectives to biological objectives. This would imply the forests are maintained at the cost of efficiency. If warranted, they should be tested in the place of FORPLAN.

From a management science perspective, until a better approach is found and tested, FORPLAN will probably remain the state-of-the-art national forest planning tool.

ECOLOGICAL ANALYSIS

Requirements for Ecological Analysis

Information Requirements

As Shugart and Gilbert (1987) suggest, NFMA sections 6(e) and 6(g) require that Forest plans consider ecological relationships and consequences. The NFMA says that Forest plans must:

1) provide for multiple use and sustained yield of the products and services of Forests;
2) determine forest management systems, harvesting levels that reflect incorporation of multiple use and sustained yield;
3) ensure consideration of economic and environmental aspects and protection of forest resources to provide for outdoor recreation (including wilderness), range, timber, watershed, wildlife, and fish; and
4) provide for diversity of plant and animal communities.

A specific provision concerning timber management and resource protection says that timber harvest activities on national Forest Service (NFS) lands cannot jeopardize soil, slope, or other watershed conditions; restocking must occur within 5 years of harvest, and where water conditions or fish habitat would likely be effected, streams, lakes, streambanks, shorelines, wetlands and other bodies of water must be protected from detrimental change in temperature, blockages in water courses, and sedimentation (Section 6(g)(3)(E)).

As Gippert (1989) points out, user groups did comment on the adequacy of ecological modeling implemented within the planning process. The lack of adequate resource response models was often

the target of this criticism. O'Toole (1986) in reviewing the Northern Arizona LRMP's says:

> Forest productivities were averaged and may have been overestimated. Planners place undue reliance on "best management practices" to protect water quality. With some exceptions, Northern Arizona forest productivities were represented in FORPLAN only as an average of each forest type and size class pg. 14.

O'Toole (1987) in reviewing the Siuslaw plan again focuses on the reliability of the response models when he says:

> The appendix rejects shelterwood cutting as "rarely practical" because of high coastal winds...Crown Zellerbach successfully used shelterwood cutting in sensitive watersheds of the Oregon Coast Range (p. 9). Projections of a 15% growth gain due to the Siuslaw tree improvement program are unjustified (p. 1). The fish habitat index model used in the EIS is overly optimistic...Due to the lack of data, the fish habitat model is speculative in many respects (p. 10).
> The EIS assumes that timber cutting will have only positive effects on Roosevelt elk herds. By ignoring everything but forage and utilizing forage outputs from FORPLAN, the Siuslaw elk model produced the unrealistic and unscientific projections displayed in the Siuslaw Draft Plan. The Siuslaw is effectively down-grading optimal cover, making the projected old-growth forest reduction appear benign in relation to elk (p. 16).
> The EIS also overestimates the ability of the Forest to support pileated woodpeckers, marten, and other mature forest species. This claim is overly optimistic because the Forest overestimates the amount of suitable woodpecker habitat due to an inadequate definition of old growth.

Swanson and Roach (1986) have examined recent landslides in clearcuts and leave areas and found that, "Considering slides greater than 10 cubic yards, the annual frequencies of sliding of headwalls in clearcuts and leave areas are quite similar and substantially higher than the annual frequency of sliding in forested headwalls." They caution that the evidence in not

conclusive, "A first impression is that headwall leave areas have not mitigated in-unit landslides. As a result, they consider the efficacy of leave areas to still be open to question."

As an example of comments made about the spatial issues involved in forest planning and management, Keller (1986) says:

> Throughout the planning process it was generally accepted that FORPLAN was not capable of modeling spatial relationships...The intuitive feeling was that with so many activity area's spread among so many stands with so many prescriptions, one would have plenty of leeway to move stands around when it was time to implement. Even though planners accepted that any given FORPLAN solution could not be put on the ground exactly, they felt they could get close enough so that the environmental and economic effects would not be substantially different from those predicted by the model (p. 124).

Industry representatives have offered other types of criticisms. Concerns about the Siuslaw and Olympic National Forest Plans raised by industry representatives included:

- The Yield simulators were inappropriate for lands with significant acres of mixed species.
- The processes used to estimate the future yield of existing stands of timber are in error.
- A full range of alternatives was not examined to deal with the headwalls. The sediment models are incorrect.
- Timber yield tables are changed without adequate justification and differ from Forest to Forest. Dispersion was not tied to Fish and Wildlife. On the Olympic National Forest the dispersion constraint was applied to acres available for timber harvest, and not the entire watershed.
- In managing for big game thermal cover, prescriptions for elk were restrictive to both elk and timber.
- Current documentation does not adequately describe (or reference) rationale for the need for MMR constraints, for the levels used in the constraints, potential redundancy of constraints, or the effects or consequences of constraints.

Another class of criticism which stems from review by "modelers" relates to the assumptions of linearity usually

incorporated into the models used by Forest analysts. DeAngelis (1987. p. 205) says that ecological systems are often highly nonlinear and in fact, under extreme circumstances, may be discontinuous. The importance of this issue is doubted by many analysts who believe that the limits of available data are taxed with the simplification of linear production functions.

Similarly, DeAngelis identifies another class of problems often noted by ecological modelers when he says that uncertainty is difficult to address in FORPLAN models, especially when the size of the model is considered. Sensitivity analysis is a partial answer, but the size of the models is considered, it is limited (Kent et al. 1988 p. 205).

The Office of Technology summed up what may be the view of many interests in stating "plan development emphasizes timber and other physical outputs".

Analytical Implications

What were the analytical implications in providing ecological information? Shugart and Gilbert (1987) say that:

> The major implication is that one must be able to consider sustained yield of all multiple-use products and services. The Forest Service is also directed to coordinate all resource management... Coordination implies to make of the same order or importance. In terms of resource management and as used in the act, "coordination" implies that no resource may be emphasized to the degree that minimum requirements for any other resource are violated (Salwasser and Mealey 1983)...it implies what has come to be called minimum management requirements must be portrayed in the analysis... Section 6(e)(2) requires some method be used to choose among alternative management systems based on their economic and environmental effects.

The evolution and acceptance of FORPLAN as this tool is described elsewhere in this report. Of significance here is that this acceptance of FORPLAN framed the context in which ecological analyses were to be fitted into the planning process. As Gilbert (1988) notes:

> A major time-consuming job during the first round of planning was the collection, organization, and analysis of resource data prior to being entered into FORPLAN. Not a lot of attention was paid to this problem at the national level, because each region was organizing things differently, and we (Land Management Planning Systems Section) were busy refining FORPLAN.

With some hindsight, we can say that ecological analyses were perceived as a data gathering effort for FORPLAN.

Ecological Analysis in FORPLAN

Shugart and Gilbert (1987) evaluated FORPLAN's ability to capture 10 ecological facets they felt were important to meet NFMA requirements. While they do not cite specific NFS plans where these facets were incorporated into the model, they suggest that FORPLAN and/or linear programming models could be adapted to incorporate some of these facets. We have used these facets to group published criticisms of FORPLAN's ability to analyze ecological dynamics.

Nonlinearities in Ecological Relationships

An example where the linearity assumption of proportionality is violated is the computation of wildlife habitat capabilities.

Holthausen and Dobbs (1985) computed habitat capability as a nonlinear function of the age class distribution of the vegetation. While age class distribution could be computed in FORPLAN, the habitat capability index could not be computed dynamically in FORPLAN. Thus, the index was computed outside the model execution and was used as an objective function in the model (Shugart and Gilbert 1987).

A combination of LP and simulation is an approach some forests took. West (1986) comments on an implementation of this approach on the Tahoe National Forest. He says that,

> The changes over time in the wildlife successional stages were further analyzed by a simulation model that predicted animal numbers based on their food and cover habitat requirements. This model was an in-house program, ran only for the key indicator species.

However the intuitive appeal of minimizing the number of analytical steps in the planning process (Shugart and Gilbert 1987) or for one decision support model (Gilbert 1988) works against the simulation/linear programming combination.

The simulation/linear programming combination is the best approach for handling nonlinearities up to this point in forest planning.

Variations in Ecological Time Scale

Resource production responses are often shorter than the rotation age of trees and there would be a significant advantage to increasing detail on the short-term and reduce the detail on the long-term. Shugart and Gilbert (1987) report that time periods

late in the planning horizon can be combined into intervals in a FORPLAN analysis, however the requirements of NFMA on how the timber analysis must be conducted limit the feasibility of this approach.

Spatial Relationships

Landscape management is manipulation of the visual and spatial attributes of a land area. Milne (1987) says:

> recognition of complex spatial structure in landscapes requires special approaches to landscape modeling. Interactions between adjacent (and perhaps distant) patches precludes simple prorating of estimates over wide areas, or among locations with vastly different environments (p.131).

Delineation of Land Units for Analysis

Delineation of land units is a key aspect of spatial relationships. Bailey (1984) reported on the results of survey questionnaires concerning land classification from 9 of 11 forests in Region 3. The following are some generalizations concerning the responses to the survey questions:

- Different terminology is used for the delineated units. The most common term is "capability area," but "analysis area," "homogeneous response unit," and "terrestrial ecosystem" are also used. This makes it difficult to generalize and make comparisons.
- There is a great deal of variation in the level of resolution from forest to forest. The number of units per forest range from 2,000 to over 13,000.
- Land delineation schemes define and capture land units by combinations of criteria which are highly variable. However the forests tend to fall into two groups:

(1) Five forests seem to be following the region's Terrestrial Ecosystem Survey procedure. Using this procedure, delineations are based primarily on homogeneity of soil types, slope, geology, and

potential natural vegetation (PNV). An additional criteria of existing vegetation is used if PNV is different, e.g., in the case of pinyon juniper woodland which has been converted to grassland.

(2) Four forests based delineations primarily on slope and existing vegetation.

- In both groups, existing vegetation is based on timber types and range types. Administrative boundaries (e.g., ranger districts) are also used if the administrative unit is different. Most boundaries are located through the process of overlaying existing mapped information.
- Wildlife habitat per se was not used to delineate units. Commonly recognized vegetation types were considered suitable surrogates.
- Predictions of timber yield, water yield, grazing capacity, and soil loss were derived through use of simulation models. Recreation and wildlife predictions were based primarily on professional judgement.
- The influence of surrounding units was generally not considered in making predictions. In other words, the higher levels of ecological generalization which aggregate contiguous units into larger regional ecosystems were not used. (For analysis purposes, units were grouped into analysis areas, but they are not necessarily ecologic.)
- There has been no quantitative testing of the predictions. Some forest planners feel reasonably confident about them; others state that there is no way of knowing for certain how good they are; one forest response indicated the predictions may have a margin of error of + or - 40%.
- One of the major reasons for the lack of testing is insufficient data. The source of data for testing is forest and range inventories. At present, the number and distribution of inventory plots are designed for forestwide analysis. When a forest is subdivided into land units there are not enough inventory plots to adequately sample each land unit.
- Several forest planners thought that, unless modified, the same units would probably not be used in the next round of planning. The modifications anticipated at this time have not been specified (p.28).

DeAngelis (1987) offers sharp criticism of the ability to incorporate landscape structure and spatial phenomenon into FORPLAN. He says:

> I do not think the degree of spatial resolution in FORPLAN is capable at this point of dealing with many of the important ecological spatial aspects mentioned earlier. However, in a gross sense, FORPLAN permits the recognition of landscape heterogeneity and makes it possible to treat land areas with high significance to wildlife in a special way. There is potential for increased spatial application in the future if necessary (p.43).

As noted above, the spatial modeling approaches used in forest analyses have been criticized by many. Iverson and Alston (1986. p. 14) say the need was for more location specificity than is provided by strata-based forest-wide decision variables.

Similarly, Hof (1987 p96) discusses the distinction between activity analysis[13] and economic production functions[14]. He discusses the importance and difficulty of accounting for the spatial layout of management options in linear programming. He concludes that this is one of the most critical and intractable problems facing forest planning. He questions the need for detailed acre-by-acre land allocations as a result of forest planning analysis. He points towards a process that produces decision rules or guidelines rather than specific numeric solutions.

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[13] Linear programming is a type of activity analysis. In a LP inputs are clustered into packages or activities and then LP attempts to solve the problem (Hof 1987 p96).

[14] A production function relates inputs (factors of production) to outputs (the things being produced) Hof 1987 p96).

The use of aggregate emphases[15] prescriptions is one approach to resolving spatial problems. Iverson and Alston (1986) say:

> Selection of a specific aggregate emphasis delimits the set of prescriptions choice for the strata-based analysis areas covered by the aggregate emphasis zone. That is, an aggregate emphasis associates a single management emphasis or a use-defined set of emphases to the analysis areas defined within an identified zone. The cost is, therefore, associated with the aggregate emphasis prescription directly rather than trying to associate it with accompanying prescriptions for strata-based analysis areas separately. Similarly, output yields such as timber harvest volume would be packaged in the individual prescriptions as before. To fully comprehend the aggregate emphasis scheme, the yield production process must be dichotomized. Some yield information (also cost and benefit information) is predicted at the analysis area level in development of prescriptions. The notion of activity scheduling for multiple resource production, and the notion of land allocation decisions being somewhat separate yet intertwined with the activity scheduling decisions, are significant milestones that set the stage for future development (p.14).

In implementing aggregate emphases and other strategies for incorporating spatial concerns into forest ecological analysis within FORPLAN, analysts have made a number of key observations. Armel (1986) says that:

> The main problems that we have encountered to date relates to the harvest unit adjacency constraints and the splitting of harvest units (pg. 146). Our experience to date has shown that there are ways to formulate the adjacency

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[15] "Implementing management plans means specific acres have to be assigned to specific prescriptions. If decision variables used in a linear programming harvest scheduling analysis are defined for stand types, then ground implementation gets little guidance from the analysis. Moreover, many important costs and impacts, which can vary substantially with site-specific implementation, often are not evaluated in the harvest scheduling model... One approach to incorporating these effects into the scheduling model is to divide the forest into logical management units for development or implementation purposes. Then these units are evaluated to decide on some implementable, on the ground allocation choices using maps, site visits, and other information. This preplanning may actually map the location of acres to be assigned to different decision variables and considered as a package by the scheduling model.... Once the choices or "package deals" have been defined for the management units, they can be incorporated into the scheduling model, forcing the model to make an either-or decision. This method of building these either-or choices into the model was developed by Crim (1980), and has been called "aggregate emphasis" technique." (Davis and Johnson 1987 p640).

> constraints to help improve the integer solution produced (p. 149).

Mitchell (1986) says:

> structuring a FORPLAN model which can be used to effectively address both the full range of timing possibilities and the crucial spatial considerations is difficult. Such an effort can soon exceed the time, budget, and manpower available on a forest.... For example, use of forestwide timber strata and theming prescriptions[16] provides an efficient means of generating a full range of management strategies for addressing timber analysis requirements. Using this type of structure, it is difficult to build in spatial, site specific considerations for other goods and services and transportation networks. Use of directly entering prescriptions and/or coordinated schedules... decrees the set of timing and management options that can be realistically modeled.

Spatial analysis is capable in FORPLAN with aggregate emphasis, coordinated schedules, or simulation, however it takes a well learned analyst to accomplish it with much success.

Variation and Error in Model Coefficients

While Shugart and Gilbert (1987) described this facet as the variation and error in estimating model coefficients, no analysis has been done as to the significance of this potential problem. Another way of examining the difficulties in assessing this problem is to review the types of outputs predicted from FORPLAN.

In developing a National Forest System Resource Interactions Model, Baltic and Hof (1988) compiled output vectors from the EIS's of Forest Plans. They say,

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[16] "A very important feature of prescription creation in FORPLAN is the ability to 'theme' timing choice, yield, and economic information to a prescription based on the prescription's characteristics" (Johnson et al. 1986 p5-3).

> the diversity of elements and their presentation across the forest models could not easily be categorized into a table of common resource outputs. In fact, indirect methods of data collection were required because not all of the model outputs were fully scheduled in the EIS's. In such cases, the missing data were either obtained from a forest or regional planning team (from other forest planning records or the team's best estimate) or estimated using the data available with regression, interpolation, or other techniques (p.7).

Baltic and Hof describe how resources were presented differently. For example, as noted in their appendix, wildlife habitat was reported as acres scheduled over the planning period, or as dollars (and not acres), or for some periods but not all periods, or as a 50 year annual average, or as wildlife projections (rather than acres), or reported for only one of the alternatives analyzed in the planning process.

This diversity in FORPLAN outputs suggests the immense difficulty in providing technical assistance to quantify the coefficients from these outputs. Different models would be needed for different outputs.

Uncertainty in Ecological Procedures

Uncertainty arises from the difficulty of predicting the behavior of ecological systems. The omission of natural disasters such as fire, and insect outbreaks, has been acknowledged (USDA Forest Service 1988b). DeAnglis (1987) says:

> The consequences of this uncertainty in system behavior is that the coefficients of the objective function and constraints in FORPLAN are necessarily uncertain. The FORPLAN approach, however is deterministic. Only the means of the coefficients are included in the analysis, not the variances, which would be large if known. The problem with this is that the analysis will compute only the most likely outcome of a particular management strategy, not the risk of undesirable outcomes (p.43).

Recommendations to improve the analysis of insect outbreaks, consequent impacts on timber growth or effects of maintenance of endangered species in the planning analysis focus on the development of additional models outside of FORPLAN.

Succession and Mortality

As Shugart and Gilbert (1987 p.111) note, "most FORPLAN model users develop age dependent relationships to help track characteristics of the vegetation deemed important from an ecological and management standpoint." They go on to note that "if the FORPLAN model had more inherent capability to track different successional stages...this would likely result in more consistency among National Forests and would also relieve some of the modeling burden from the analysts." An approach for examining differential regeneration success, stand mortality and a general decision tree approach were reported to be incorporated into Version 2 of FORPLAN (Shugart and Gilbert 1987).

Vegetative Structure

The description of the vegetation structure was focused on timber in Version 1 of FORPLAN. While Version 2 has more flexibility to handle multiple storied stands, Shugart and Gilbert suggest that "this will add to the complexity and cost of the model, not to mention the way it would test the user's creativity and gumption."

Ecological Analysis: the-state-of-the-art

Resource Analyses

Some have argued that better ecological models are not needed. For example, Gippert (1989) says that:

> The Forest Service has found that often these projections do not match what is found upon specific site examination. This is inherent in modelling projections of possible resource output for 1-2 million acres over long periods of time p. 5...Sometimes too much emphasis on the output projections has created unneeded controversy and focused the opposition to LRMPs (both from industry and environmental groups) on the wrong issue---perfection of computer modelling and data bases. A more meaningful focus for review of LRMPs is the management direction.

Gippert's tone is that precise response forecasts are unnecessary. This would surely be debated by many forest analysts and forest researchers. Forest Analysts had a wide range of reactions to problems and successes that they encountered during the planning process. In contrast to Gippert, Barber (1986) says:

> There is a great need at this time for better FORPLAN analysis, but more important, there is a need for better theory and rigor related to development of production and trade-off functions.

In a later section of the same paper he says:

> This paper is not intended to be anti-FORPLAN, only anti-large model. This Region has attempted to predict outputs and effects without FORPLAN by using professional judgement of the forest ID and management teams. The teams always over estimated the outputs and under-estimated the effects. When the same test was given to District Ranger and their staff (the doers), they tended to under estimate the outputs and over estimate the effects.

Barber argues for more precise ecological forecasting models. This is a common suggestion made by analysts and forest managers.

Troyer (1986) provides a summary of much of what analysts and forest managers positions when he says:

> Even though we quantify more and more of our resources, quantitative multi-resource solutions in most of our resources will always be debated. Recreation, water, wildlife even visual values are quantifiable but arguable. Therefore, there is always an ultimate limit to the value of a FORPLAN solution in multiple use management no matter how sophisticated we chose to make our model.

Researchers and experts outside the Forest Service made similar observations. In commenting on the selection of modeling techniques which subsequently affected the Forest's ability to incorporate ecological phenomenon, Johnson (1987) says that the problem of emphasizing economic efficiency versus estimation of environmental effects needs further work. He says this problem manifests itself in the selection of optimization over simulation approaches. He goes on to say the selection was in part driven by the nature of the NFMA planning process. Given that optimization techniques set side-boards on what could be accomplished, Shugart and Gilbert (1987) say that:

> The struggles in trying to incorporate ecological processes into FORPLAN brought up issues related to the objectives of the FORPLAN model. In every attempt to quantify ecological processes in FORPLAN, model size, or duration of model run (and consequently model interpretation) becomes the real problem. As a result of this need to restrict model size, the "dilemma is deciding how much detail should be carried in the forest planning analysis tool and how much should be handled in separate steps.

DeAngelis (1986) points out the difficulty of representing nonmarket valued commodities and ecological considerations in a model based on a financial criterion of optimality.

As Gilbert (1988) points out, much effort was expended at gathering data on resource production responses prior to the FORPLAN analyses. In addition, ecological analyses were used to analyze outputs from FORPLAN runs, such as the assessment of wildlife habitat capability. These efforts ranged from quantifying best management experience to developing and exercising hydrological models, wildlife habitat capability models, or timber growth and yield models. No formal criticism of all of these resource processes has been published.

Schroeder, Johnson and Dolph (1989) summarized a critique of the timber growth and yield models. They say:

> The trend is for Regions to utilize a single growth and yield system rather than having each developer develop a complete delivery package....Because of the diversity of the biological relationships portrayed by growth models, there is a tendency to decentralize growth function development...Few of the Regions or Stations mentioned maintenance, management, and installation of permanent plots in their action plans. For the development or improvement of growth models, permanent plots are still the best source of data to reflect a wide range of possible treatments...In units which have been using models for some time, an evolution of modeling which involves the integration of timber growth models with models used by other resources is evident. This is happening with wildlife, watershed, and visual management. Frequently this requires analysis at a level of resolution larger than the stand level. Models generally referred to in the growth and yield plans are for simulation of normal conditions. If an effect of some pest is desired, the normal condition must be modified. As basic timber models come on line they will be expected to include pest impacts shortly thereafter. An important feature of a simulator which will deal with uneven-aged management is a component which will allow for the introduction of regeneration and has adequate functions for the growth of small trees. Many simulators lack this key component and few of the Region and Station plans addressed the issue. This part of the growth and yield action plan should also be supplemented with current thoughts including the handling of cull, mortality, and pest impacts (p.1-2).

A Forest Service Task Force on Range Measurements concluded that:

> using the existing measures of range management, the status and health of range resources are not being adequately portrayed to the Agency, Department, Congress, or constituent groups. The primary measures traditionally reported have been range condition and numbers of animal unit months (AUMs) of livestock grazing. Range condition is slow to change, often taking decades; and the number of AUMs of grazing authorized does not accurately reflect the amount of forage actually utilized.

Kent and Gilbert (1988) note that:

> One of the major outcomes of the forest planning analysis process has been increased awareness of the voids in our knowledge about multiple resource interactions. We are finding that many of our traditional assumptions about the production relationships in forests are being called into question both by staff specialists and by the public. Some of these deficiencies came to light early on in the planning process when efforts were made to quantify production relationships for inclusion in FORPLAN. Also production relationships that were developed five or six years ago are now being questioned by interest groups. This is not meant as a criticism of the work done by planners and functional specialists. They played the difficult role of moving their disciplines forward by forcing researchers and inventory specialists to make their results relevant to management's needs. Rather, it points out the need for ecologists and scientists to work with resource managers and specialists to clearly describe the significant production relationships necessary to make management decisions.

One of the limitations in developing ecological analyses is the availability of inventory information. The success of timber growth and yields models is related to the common acknowledgement of the type of data needed from inventories to calibrate these models. In other fields, the lack of a commonly accepted analytical tool restricts the efficiency of inventory design. Developing models from available data, a likely alternative for this round of planning, yielded a diversity of models and model

outputs. This diversity of outputs was reported by Hof and Baltic (1988). The diversity of inventory measurements was a conclusion of the Resource Information Project (RIP) (USDA. Forest Service. 1988a).

In examining the availability of basic information such as vegetation and soils, the RIP team discovered that:

- Twenty-six different vegetation surveys were used on 34 forests. On the average, each forest used 14 vegetation surveys to collect information about existing vegetation. The team identified 59 attributes collected on the surveys. Of the 59 attributes, information about 9 of them comprised 62% of the information gathered. And only the 9 were used on all 34 forests (p. 18).
- Of the 6 resources RIP examined, only soil was described, and organized consistently all 34 sample forests. The characteristics and classification for soil resources are based on schemes used by the Soil Conservation Service. The standardization of terms and the classification scheme make information about soil resources consistently collected and sharable among forests and across agencies (p. 18).
- Of the other resource components, the team found a range from much consistency in approaches or terminology to none in either. Standardizing terms, codes, and formats will have a big pay-off in terms of understanding information collected at another site and knowing that it means what you think it means (p. 18).
- Based on the sample results, 62% of the forests visited had "standard definitions" for the landshapes they recognized. Three discrete landshapes descriptions were found most often during the sampling process; mountain sideslopes, rounded ridgetops, and valley plains...landshape information is widely used across the Forest Service as a means of communicating about basic data. The sampling process highlighted the varied approaches that are currently used regarding landshape information. Many national forests viewed landshape information in terms of discrete landshapes. These discrete units were mapped as a part of basic resource inventories and used as a basis for developing resource interpretations. The sample also showed that many forests view landshape information in terms of the analysts individual attributes which collectively define a discrete landshape. Landshape attributes (such as slope shape and slope gradient) are often major components used in developing interpretation,

and they are often used independent of the discrete landshapes (p. 60).

- The data suggests that a set of landshape attributes is used by most national forests. Attributes such as slope gradient, slope shape, landshape relief, slope characters, and drainage dissection were commonly used. However, the definitions for these attributes and how consistently they were used did vary considerably (p. 60).

In suggesting what should be done, Shugart and Gilbert (1987) imply criticism of some forest planning analyses. As an alternative, they propose a modeling framework that combines simulation approaches commonly used in ecological sciences with LP models to utilize the appropriate strengths of each in the exploration of resource production potentials. The FORPLAN model in this hierarchy becomes a land allocation and activity scheduling model where the inputs have been derived from the smaller scale models and outputs have been examined in the larger scale models.

Joyce and Milne (1987 p209) also recognize that resource production analyses need to be quantitatively linked in the planning process but not necessarily in one model, resource interactions occur within different spatial scales, resource interactions occur within different time scales, and there is a need to incorporate the information between spatial and temporal scales in planning.

Improvements most commonly suggested to deal with the inadequacy of FORPLAN as an ecological tool were models specifically developed to describe resource production outside of FORPLAN.

ECONOMIC ANALYSIS

Economic efficiency analysis was imbedded in the objective function of FORPLAN's LP structure. As expected, the model maximizes net present value subject to a set of constraints. The general structure of the objective function is the sum of the present values of revenues minus the present values of the costs:

$$Max\ Z - \sum \frac{R_t}{(1+i)^t} - \sum \frac{C_t}{(1+i)^t}$$

where
R_t = revenue occurring in period t
C_t = costs occurring in period t
i = interest rate.

Economic Efficiency and Planning

There has been extensive comment on the role of and appropriate formulation of economic analysis within the Forest Service planning process. As noted above, Schweitzer (1983) says, "Perhaps the outstanding single characteristic of the planning process is that it is rational...However, the rationality is bounded...A third characteristic is that planning activities are all to be public....A fourth major characteristic of current forest planning is the continued reliance on subjective choice. These observations suggest much about the role of economic analysis in Forest LRMP. Economics is but one

input into the "subjective" choice process and it seldom should be expected to identify the preferred alternative for a Forest.

Dennis Teeguarden, a member of the Committee of Scientists, says:

> The National Forest Management Act directs the Forest Service to incorporate economic principles into its forest plan decision making. However, inadequate empirical evidence of the value of some national forest outputs limits the ability of the Forest Service to accurately measure the economic efficiency of alternative plans. In addition, the Forest Service should balance its consideration of economic efficiency with consideration of the equity for distributing national forest benefits to various user groups. Despite these limitations, benefit-cost analysis is a useful tool that reveals the potential economic consequences of alternative plans, helps mitigate the potentially extravagant claims of interest groups, and provides a guide to selecting the economically efficient output level for priced resources (Teeguarden 1988, p. 393). The RPA/NFMA does not establish a strategic objective for the planning process. Nevertheless, the Committee Of Scientists and others recognized a need for a conceptual goal to guide the implementation of the NFMA regulations. Accordingly, the 1979 regulations adopted the principle of maximizing net public benefits, but left the term undefined (p. 406). The NFMA regulations do not state explicitly the conditions for designing economically efficient programs. Instead, they provide a process for developing internally efficient alternatives, constrained by specific resource protection standards and unpriced objectives, and subjecting these alternatives to comparative evaluations pursuant to the requirements of the National Environmental Policy Act of 1969. The primary use of economic standards in this process is to assist in defining alternative land management programs and to provide information on their economic consequences rather than to make the decision (p. 407).
>
> It is important to distinguish between the concepts of net public benefit (NPB), as defined above, and present net value (PNV). The NFMA regulations define the latter as: "the difference between the discounted value (benefits) of all outputs to which monetary values or established market prices are assigned and the total discounted costs of managing the planning area. Thus, PNV includes only priced outputs. In practice, the priced outputs include timber; range forage; recreation visitor-days including those for wildlife, fishing, and wilderness experiences; minerals; and the value of increased water-flows. Excluded are such unpriced benefits as visual amenities, biological diversity, preservation or

> enhancement of threatened and endangered species, and the values of natural or scientific areas (p. 410).

In a narrower characterization of what NFMA and the regulations require, Krutilla, Bowes, and Willman interpret the intent of NFMA as a mandate to manage the National Forest System lands as an "economic asset" with an objective function of maximizing net social benefits; these benefits would be measured in monetary terms and forest management would be subject to specified constraints relating to certain nonmarket resource outputs and services required under multiple-use legislation. Thus for these authors, NPV constrained by various other objectives would be the decision criteria. How well did the forest respond to these directives? Some have argued not very well. The National Wildlife Federation appeal of the Siuslaw National Forest Plan asserts that the Forest Service did not accurately assess economic and financial consequences of proposals and that this lead to an unrealistic set of proposals for harvest levels and intensive timber management. This is an extreme position, but not an unusual one. The details of economic analyses have often become the focus of discussion by user groups that question the appropriateness of the recommended plan. It often seems that debate about economics is the "handle" they use to express their dissatisfaction with proposed actions.

Further findings in the surveys by Hoekstra et al. include the statement that Present Net Value should continue as a principal focus of attention for developing alternatives, but focus should

be broadened to include the distributional consequences of the alternative.

General Critique of the FORPLAN Economics

What has been the general reaction to the forest's economic analysis? The most obvious place to begin this discussion is with the economic analysis done within FORPLAN. In a national symposium organized to evaluate FORPLAN, Beuter and Iverson (1986) presented a paper on the economic aspects of FORPLAN. The central theme of Beuter and Iverson (1986) is that a system such as FORPLAN cannot possibly determine a thorough and precise optimal solution to the forest resource allocation problem encountered in Forest Planning. In evaluating FORPLAN as an economic tool, they identify several characteristics of an "ideal forest planning model" that also suggest research priorities. They note that the ideal should: be capable of maximizing net social welfare, consider the long run, distill all that is known about markets and seek an efficient allocation of factors of production to meet demands for goods and services from the forest, and easily (analyze) trade-offs between different forest resources. In pulling the above observations together, Beuter

and Iverson note the important trade-off between technical capability of a system such as FORPLAN and complexity that makes understanding difficult. They also point out that the "link between operational feasibility and forest plans is tenuous." They conclude that "it is debatable whether it (FORPLAN) should be used for large-scale, forest-level planning." They note that Version 2 may be best suited to site-specific project analysis. They observe that "there has been little effort to develop national forest plans with sensitivity for the management of surrounding lands." They cite Johnson and Greber (1986) in Oregon as an example of a more complete view (Kent p. 207). These are precisely the issues relative to economic efficiency which have be raised by many Forest Service critics.

Krutilla and Bowes 1989 make a related point:

> when we consider the related task of estimating the economic values of the biophysical results from increments in management inputs, we have another large area for improvement. Without the information on the biological or physical output response to increments in management inputs, it is very difficult to evaluate the economics of alternative management regimes (p.747).

The sense that emerges from these critiques is that economic analysis is needed, but it may be flawed as implemented in FORPLAN.

Instructions for Implementation of Economic Analysis

The Forests receive extensive instruction from both regional and national levels during the planning process. There was generally clear and consistent, though not always detailed, instruction to

complete economic analyses "in the spirit of" the Teegaurden quote.

MacCleery (1981) says:

> The role of economics in planning is key. Economics provides a structured way to analyze trade-offs and to measure and compare priced and non-priced objectives...Assuming we were confident of our model, our values, and output production functions, the maximum PNV solution would be socially optimal. Since we can't place dollar values on all resources, such resources must be handled as constraints, i.e. met at some arbitrarily specified level. And where we don't know production functions we should be honest about it and not delude the public (or ourselves) by making more out of the data than is warranted...FORPLAN is an economically driven model ...Planning should begin with a maximum present net value (PNV) analysis constrained only to meet minimum legal requirements. Planning should then proceed systematically to incrementally impose constraints in a logical sequence, so that there can be an evaluation of trade-offs between priced and non-priced objectives during the process of generating alternatives...The economic cost of constraints is represented by the reduction in PNV that results from their imposition... Ideally, the economic analysis should seek, at a minimum, to provide the following kinds of information: 1. Maximum supply capabilities, both biological and economic. 2. Information on the economic relationships and efficiency between alternatives. 3. Information on economic efficiency within alternatives, i.e., are the specified constraints most efficient to achieve the non-priced multiple-use and environmental objectives with the least impact on PNV?...All other things equal, I see no reason why there should not be at least one formal planning alternative that maximizes PNV subject only to minimum legal constrains needed to make the alternative implementable and feasible (p. 4-11).

Crowell, past Assistant Secretary of Agriculture, says:

> In many cases the economic implications; of many Forest Service policies, such as non-declining yield harvest schedules, rotations based on biological criteria, and the effects of meeting various nonmarket, wildlife and environmental objectives have not been adequately evaluated or considered in Forest Service decision making. First, economic efficiency is but one criterion to be used in decision making (Crowell 1983, pp. 1-2).

What Was Done and What Problems Were Encountered?

In describing the way these directives were incorporated into FORPLAN, Teeguarden (1988) says:

> FORPLAN uses linear programming to simultaneously determine the land allocations and activity schedules that maximize present net value subject to such other goals and objectives as might be prescribed by the constraints. Thus it is the primary administrative tool for incorporating economic efficiency criteria directly into the development and evaluation of alternative forest plans...Objectives and polices relating to unpriced resources are set at prescribed levels through the use of constraints (p. 420).

Palmer, Row, and Randall's (1983) comments on the difficulties forests encountered captures what is probably the consensus position on the job forests were asked to do:

> The Forest Service has adopted a unique framework for economic analysis to deal with the difficult problems the law forces us to face:
>
> - Production processes that are technically complex and specific to numerous on-the-ground conditions.
> - Varied outputs and effects that must be recognized include those that (a) have market values, (b) could have market values, (3) provide no basis for market-like values.
> - Large comparative advantage among analysis areas within national forests, and among forests and regions, that require mathematical programming techniques to identify the most efficient alternatives.
> - The limits of state-of-the-art of economic methodology prohibits computation of a single comprehensive measure of economic worth and thus the identification of an "optimum" management alternative (p. 40).

In an almost prophetic statement Row (1983) said:

> But from the range of comments a wide range of issues related to the economic analysis might be attacked in various plans. These may include:
>
> - the discount rate of 4% prescribed in FSM 1970 for long-range Forest Service planning. This is substantially lower than those used for other federal agencies, though based on substantial economic rationale.

- the role of the economic analysis on the suitability of land, and the use of the information in development of alternatives.
- the degree to which the economic information on cost and output values are specific to individual analysis areas, especially in comparison to the site-specific of the biological and physical information.
- whether the economic analysis is hiding any alleged subsidies (p. 9).

Demand Analysis

The forests rarely estimated demand functions for their outputs. Rather, they followed regional and national direction and assumed that the demand functions they faced were horizontal at a market clearing price. Market clearing prices were typically defined through reference to national or regional demand analyses. As might be expected, the use of national or regional forecasts and the assumption of a horizontal demand schedule at the market clearing price was often greeted with skepticism. Most critics agree that this procedure would be consistent with the circumstances faced by a firm in a perfectly competitive market which could not affect the price of its output by varying the amount offered. Teeguarden (1988) says:

> The FORPLAN model allows for the specification of step-wise linear approximations of demand curves for timber and for any other resource output...However, demand schedules are usually represented in a two-step form: quantities up to the amount produced are assumed to be sold at fixed average price, while quantities greater than that amount have zero value. In effect, within a specified range, it is assumed that price, whether market determined or assigned, is invariant with

> respect to the plan's outputs. This may be an appropriate assumption for a commodity such as timber, which is sold to a regional or national market, but not for recreation, water, or game wildlife which tend to be valued by local or state level demand...So far, little attention has been paid to this demand side of forest planning (p. 423).

Extensive literature and concern exists which indicates that the assumption of horizontal demand may not hold for outputs such as developed recreation and wilderness. It is asserted that action by the Forest Service often changes the market circumstances enough to affect price or values. Similarly, the Northwest Forest Industry Association commented that the timber programs of the Siuslaw and Olympic Forests in concert with actions of other forests would change the market supply to the point that prices would be affected. This suggests that assumptions of horizontal demand may not always be appropriate for timber. Therefore, in the case of specialized management actions such as recreation and wilderness and in any cases where the forests' output will likely change the market price, it is clear that the forests should estimate demand functions.

There has been many papers discussing estimation of local or regional demand for timber (Haynes et al. 1981, Adams 1983, Connaughton et al. 1983, Majerus et al. 1989 and Connaughton et al. 1989). Greer (1986) was able to demonstrate the process of incorporating demand schedules for timber into FORPLAN for the Deschutes National Forest.

Estimating demand functions for other resources seems to be much less published, however Sorg and Loomis (1984) thoroughly cover the subject.

Krutilla, Bowes and Wilman (1983) emphasize the importance of better demand analysis when they say that the demand side should receive the highest priority for further research because the theory is less developed and the problem more complex.

Many respondents to a survey of analysts and planners say demand was rarely quantified as a price/quantity relationship--but usually historic and expected consumption (Hoekstra et al. 1989). Further they supported Teegaurden's usual approach to demand information was to define it as a fixed price with a "cut-off" constraint in FORPLAN. Empirically, this was probably as good as could be expected. Unfortunately, this makes the utility of non-market benefit values largely superfluous.

Prices and Values

Because most of the forests used RPA values and prices in their analyses, it is necessary to look at what commentators have said about RPA economic analysis. Peterson, Brown and Rosenthal (1987) in defining approaches to determining prices and values offer suggestions on what should be done in forest planning:

> There are two basic approaches to estimation of an RPA value: (1) observation of demand in real markets; and (2) observation of demand in hypothetical markets. In either case, marginal and nonmarginal change must be clearly distinguished. A marginal change does not significantly change prices; a non-marginal change does. For marginal change in the quantity of on-forest product, the appropriate National Economics Development value is the price that would be defined by perfectly competitive equilibrium between on-forest supply and demand, where

> marginal willing to pay equals marginal cost. Here only one point on the demand curve is relevant. For non-marginal change, the value of a supply change is again net willingness to pay for the change; but this must be calculated by integration of the on-forest demand function over the range of the price change. The appropriate National Economics Development value is then the per-unit willingness to pay (the total divided by the quantity change) (p. 13).

One summary of their disaggregation philosophy is indicated by this statement:

> Disaggregation of the national economic development RPA value into government revenue, consumer surplus, and net private revenue components is one way to assess economic impact. It is exposure of the changes in wealth of the government, final demand, and private industry sectors of the economy (p.12).

In commenting on different accounts they say:

> RPA values are to be defined relative to the National Economic Development account to measure achievement of the economic efficiency objective (p. 9).

They also note that:

> The value of an on-forest product can vary by production location if there are differences in access to markets and, hence, differences in shipment costs, or if there are differences in local site attributes that cause production and extraction costs to vary from place to place. Therefore, it would not be reasonable to expect a single RPA value to be valid region-wide for a forest product (p. 2).

Randy O'Toole offered numerous observations on the prices and values incorporated into the FORPLAN analysis.

> Data and assumptions in forest planning models which may be questionable include timber prices, projected future timber values...(1986, p. 19).
> While it is impossible to estimate the value of cultural resources in the Santa Fe National Forest, it is possible to show that much of the timber in the Santa Fe is

> worthless---so why disturb the cultural resources? (1986, p. 37).

In commenting on the Siuslaw plan, O'Toole (1987) says:

> Timber prices in FORPLAN were more than twice as high as the prices recently bid for Siuslaw Forest timber. By basing timber values on prices paid between 1977 and 1983, planners were using the period when purchasers were bidding record amounts for timber...High prices in FORPLAN are compounded by the assumption that timber prices will continuously increase over the next 50 years. Because timber prices are so high, trends have little effect on the Siuslaw FORPLAN model...Assumed timber prices were too high (pp. 1-3). In a 1986 review of Northern Arizona Plan, O'Toole says: Whether or not the values are too low makes little difference to the Northern Arizona FORPLAN models. Virtually all of the recreation benefits were entered as themed prescriptions rather than related to any management prescriptions or outputs. Thus, planners, rather than FORPLAN, had complete control over the projections of recreation outputs (p. 23).

In his most direct criticism of RPA values in his Review of the Northern Arizona plans O'Toole says:

> "Planners based recreation values on the 1985 RPA Program. Typically, these values range between $5 and $15 per visitor day (12 hours of recreation). The numbers were obtained from a literature review conducted by Sorg and Loomis (1984), recreation economists, under contract to the Forest Service. At the direction of John Crowell, then Assistant Secretary of Agriculture in charge of the Forest Service, the Forest Service arbitrarily reduced the values estimated by Sorg and Loomis by 37 1/2 percent in 1983. As described in Cascade Holistic Economic Consultant's review of the draft program document, there is no valid reason for such a reduction (pg 23).

O'Toole makes two points most critics have accepted:

> Non-market values used in plans had little effect on the optimal solution because of constraints i.e. FORPLAN and/or high returns from timber harvesting relative to other outputs. The reduction in the Loomis-Sorg values had little basis in theory or literature.

Hoekstra et al. states respondents indicated,

> - This problem is exacerbated by the current direction offering three "choices" of non-market values to be used in Forest Planning. Current policy is unclear which (or perhaps all) of the prices are appropriate.
> - Analysts had little faith in the credibility of benefit values. Where it was important (e.g., timber) Forests invariably estimated their own values rather than use RPA values.

Supply Analysis

Very little work was done by forests to estimate economic supply schedules that reflected the marginal costs of producing outputs. As an alternative, they usually defined the output levels stemming from the various alternative plans as the "supply" available. This was then associated with the horizontal demand schedules described above to define the output level where consumers or users would not pay for or value additional output. As with demand, when forest alternatives result in changes in the market that lead to price or value changes, it is essential that a supply schedule be estimated. Without this information, it is possible that outputs will be produced with marginal production costs which are higher than price or alternative value.

Cost Analysis

While it is tempting to assert that the forest should estimate per unit costs for each of their outputs so that a benefit/cost comparison can be made at the unit output level, the structure of

FORPLAN makes this unnecessary. This is a particularly useful result because it is often difficult to separate costs by output when multi-product prescriptions are used. Regarding the so called joint cost problem, Krutilla Bowes and Wilman (1983) say that costing prescriptions rather than outputs makes this a "false" issue.

There are, however, many criticisms of the data used to assign costs to prescriptions or the way the data were used to develop prescription costs. While the specifics of the criticisms are often missing, commentators believe cost estimates are incorrect. For example, the wood products industry questioned the costs of planting used in the Siuslaw plan. They compared them to costs reported by industry, and asserts that they are much too high (Hamilton 1987).

O'Toole (1986) says:

> In fact, roads are generally built deep into roadless areas to reach timber sales. This is necessary to ensure that clearcuts are well dispersed...The proper way to account for this is to count the discounted values of all future road costs against the discounted value of all timber which will be accessed by those roads...The Forest Service sometimes erroneously applies a depreciation factor to account for road costs. Planners might assume that roads will be depreciated over a 20 year period, and account only one-twentieth of the costs against the timber sold this year. This usually improves the economic analysis. However, it is valid only if planners can show that the amount of timber which can be sold from the road is equal in each of the next 19 years to the amount sold this year (p.).
>
> Shelterwood cutting is said to be more expensive than clearcutting, but the Forest Service rarely counts the added costs of reforestation and brush control when it compares clearcutting with shelterwood cutting. A detailed analysis might show that shelterwood cutting is economically superior, particularly when natural

> reforestation after shelterwood cutting is fairly reliable (P. 33).
>
> Most road and certain other timber-related cost were fixed as well, even though such costs would vary with the level of timber output (p. 3).
>
> The costs of roading roadless and relatively roadless areas were not reflected in the models (p.).

One reason that there has not been more criticism of costs may be that there is a perception that changes in cost estimates do not affect the optimal solution derived from FORPLAN. O'Toole's comments have more to do with trying to isolate the economics of timber management programs so that below-cost timber sales and negatively valued future period investments in second growth timber management will not be masked by the high returns associated with first period harvests. He is asking for a separate economic analysis of the timber program more than a revision of costing procedures.

Hoekstra et al. respondents said,

> - the following technical issues should be addressed (and policies established to provide guidelines): 1. Costs should be based upon "charge as worked" 2. Costs should distinguish between fixed and variable costs 3. Avoid forest-wide cost averages.

Discount Rate

Teeguarden and O'Toole offer contrasting views in the role of the discount rate in forest planning. Teeguarden (1988) says:

> Ultimately, the selection of a discount rate is a policy decision rather than technical decision. However, as a

> guide to policy makers, it is useful to have an estimate of the opportunity cost of federal capital funds. Conceptually, the most accurate measure of opportunity cost is the value of capital in the use to which it would have been put by private businesses and households had the same funds not been withdrawn by taxes for public expenditure (p. 416).

O'Toole (1986) gives us a sharply critical point of view (not necessarily a consensus view) when he says:

> What discount rate should the Forest Service use?... Unfortunately, the Forest Service uses a discount rate which is significantly lower than private industry (p. 12).

Effects of Constraints on Economic Efficiency Analysis

Teeguarden (1988) says:

> Other elements which confound an economic efficiency interpretation of planning alternates generated by FORPLAN are the legal limitations on the level of timber sales and rotation selection...The identification of marginal timberlands serves to illustrate the distorting effects that such constraints can have on application of economic efficiency standards to forest planning issues. Areas exist on many forests that will have a negative PNV if scheduled for timber harvests. Considered on their own merits, such areas are economically inefficient for timber production: discounted investment and management costs exceed the anticipated benefits. Without the even-flow constraint, a FORPLAN analysis aimed at maximizing PNV would exclude such stands from timber management (pp. 423-424).

This is the same point O'Toole makes in his criticism of costs in his critique of the Northern Arizona plans.

McQuillan (1986) says:

> The contribution of volume from these negatively valued stands tends to raise per-decade harvest levels in later decades, and substitutes for volume from positively valued stands that can then be harvested in the nearer future. Because of the effects of discounting, the net contribution to total NPV or NPB is positive whenever the addition to net discounted value from the increased harvests of positively valued stands in early decades exceeds the negative effects of harvesting deficit stands in later years (p. 963).

This is a clear explanation of the technical reasons for the timber sale related issues that O'Toole has consistently criticized.

In a general comment on constraints, Crowell (1983) says:

> A related common problem is that some planning teams have inappropriately assumed a role of negotiating constraints and resource objectives amongst themselves, rather than adhering to their proper role of objectively evaluating the biological and environmental effects of various management options for consideration by those in line authority. This negotiating process can have the effect of dealing the decision maker and the public out of the decision making process, and could subject the plan to successful legal challenge (p. 13).

As noted by Hoekstra et al. (1989), Minimum Management Requirements (MMR) constraints have also been criticized as being arbitrary and/or not supported by scientific evidence. These criticisms have usually come from the timber industry and assert that MMR constraints unnecessarily restrict the lands available for timber management.

Trade-Off Analysis

Teegaurden (1988) says:

> consider the problem of comparing alternatives as opposed to designing alternatives that in some sense are internally efficient, given the constraints...Recall, however, that the unpriced outputs are represented by the constraint package that is unique to each particular alternative...While it is possible to examine the sensitivity of the objective function and solution to these constraints, the benefits realized from them are not valued in the PNV analysis...So returning to the caveat made earlier, PNV is only a partial measure of the overall economic efficiency of the alternative and cannot be used legitimately to compare or rank plans (p. 425).

Davis (1985) in discussing the possibilities of meaningful trade-off analysis with a "fixed constraint set" (Type A) and a "varying constraint set" (Type B) says:

> The conditions determined for locating a problem solution that can be labeled economically efficient are (1) the problem is specified by a single set of goals and constraints, (2) the same explicitly and implicit set of output values are used to evaluate all candidate solutions, and (3) some sort of a systematic search of the full region of feasible solutions is made. These conditions are satisfied only by solutions arising from a type A process. More importantly, alternative problem solutions from a type B process cannot legitimately or meaningfully be compared by the criteria of economic efficiency. Many forest management planning problems are found to inherently use a type B process to generate alternative plans (p. 2).

Connaughton and Fight (1984, p. 680) make the same point:

> Trade-offs cannot be reliably computed from the differences between land-management alternatives. Trade-offs may be overstated when inputs such as land are manipulated instead of outputs. Though comparing alternatives is an essential and informative step in selecting a preferred alternative, comparing mixes of outputs from different alternatives will not generally determine the rate at which one output must be sacrificed to increase another. A trade-off is computed as the change in the objective function resulting from a

> change in one of the output objectives or management policies of an alternative. In discussing an example where two outputs goals are varied simultaneously they say: The $55,000 opportunity cost is due to the changes in both the elk and the owl objectives, yet the entire opportunity cost is attributed to the change in the owl objective alone (Connaughton and Fight 1984, p. 682).

Lands Suited For Timber Production

The economic test within the lands suited for timber production have been discussed by numerous commentators. O'Toole (1986) says:

> We now know that we can make money selling existing timber from roaded Douglas-fir lands, but that managing such lands for second-growth will lose money. Under the current Forest Service planning process, such lands would readily be included in the timber base...For sustained yield management, the timber base should include only those lands which can produce positive values from investments in reforestation and other management practices. Lands which make money on harvest of existing timber but can't produce a reasonable rate of return on second-growth investments should be outside the regulated timber base. Such lands could still be "mined" for their timber, when such mining produces positive economic values (pp. 27-28). A cost-efficient suitable timber base should include only those acres needed to sustain the proposed first decade level of timber sales. Yet many forest plans include far more lands...Over half of the forest plans in the country may suffer from this problem (p. 36).

As O'Toole's comment suggests, analysis of regeneration and site preparation following harvest of an existing stand continues to be a point of contention. In contrast to O'Toole, some argue that these costs are really operation or current period costs associated with the harvest of an existing stand and necessarily should be associated with the revenues from the initial harvest.

Given regeneration language in the NFMA regulations and the general expectation that sites will be regenerated within 5 years of harvest, one can reasonably accept this position. Others support O'Toole and take the "bare ground position" and assert that these actions are investments associated with the subsequent and future harvest on a site and should be associated with those revenues.

Finally, O'Toole (1986) offers a view that is becoming a common characterization of multiple-use management and its relationship to lands suited for timber production.

> Many current sales are "cross-subsidized", reducing income to federal and county governments...Below cost timber sales cannot be justified by wildlife habitat needs...Below cost sales cannot be justified by recreation needs...Planners overestimated demand for both timber and domestic forage (p.1-2).

Regional Economic Analysis

The input-output model (IMPLAN) used by the Forest Service is as follows (Miller and Blair 1985):

$$\bar{X} = (I-A)^{-1} * \bar{Y}$$

where
- $(I-A)^{-1}$ is the matrix of output multipliers (Leontief inverse) with the identity matrix (I) and the technical coefficient matrix (A).
- Y is the vector of final demand changes
- X is the vector of changes on output to satisfy the final demand.

Criticism and comment on the Forest Service approach to regional impact analysis has been sparse. In fact most comments

have been on policies related to community economy enhancement and the relationship between these and the timber program. O'Toole (1986) says:

> The Forest Service has sometimes created an artificial source of employment by subsidizing local timber and grazing industries. It is often difficult to explain why such subsidies should not continue. There is no doubt that loss of employment can be traumatic for the individuals and families involved...The total cost of the timber or grazing program can be divided by the number of jobs directly related to the program to estimate the cost per job. On many national forests, this cost is actually more than the workers are collecting.

Helfand (1983) in an appendix to the Wilderness Society Citizen Handbook says in commenting on the Grand Mesa-Uncompahgre-Gunnison plan:

> It is somewhat curious that the region bases its timber goals on purported community needs, since the surrounding communities do not appear to be timber-dependent.

O'Toole (1986) says:

> Supposedly, non-declining flow protects community stability---yet there is a large body of research which shows this is not true. Non-declining flow may also protect wildlife, watershed and scenery, but since those values can be quantified elsewhere there is no need to use non-declining flow as a proxy for them. Non-declining flow seems to be used mainly as justification for the Forest Service to spend millions of dollars each year on practices which have a negative value.

While there are concerns, IMPLAN seems to be accepted as a reasonable model for estimating income and employment impacts of Forest plans.

RESEARCH NEEDS FOR LAND RESOURCE MANAGEMENT PLANNING

Hoekstra et al.(1990) state the overall problem with current agency planning analyses is concentrated in two areas.

> First, these analyses are extremely complex, difficult to understand and communicate, and expensive. Second, these analyses have shortcomings in their capabilities, the alleviation of which with current technology would certainly increase the degree of complexity, etc. The problem is thus to find simpler, less expensive approaches to accomplish current capabilities, and at the same time expand capabilities.

They indicate there are four areas where research is needed,

1) improvement of FORPLAN
2) investigate fundamentally different planning approaches
3) improve linkages and interactions in the planning problem
4) investigate risk and uncertainty in resource planning models.

Improvement of FORPLAN

Hoekstra et al. 1990 indicate the critical research needs related to improving FORPLAN includes reduction of analysis detail over time, investigate nonlinear approaches for use in FORPLAN, and redesign of user interface of the system. Other simplifications may include development of procedures for quick sensitivity analysis, increased solution efficiencies, development of methods for defining minimum management requirements.

Different Planning approaches

They emphasize the need for research on fundamentally different planning approaches such as multistage planning

approaches which solve the strategic, tactical, and operational planning in stages, the restrictive temporal equity or generally even flow constraints, and open-ended forest planning analysis. Further research in this area may include utilizing simulation approaches with or instead of optimization, and use of ecological diversity as the optimization criteria.

Improve Linkages and Interactions

Hof (1988) states high priority areas for research include accounting for linkages and interactions between resources, between administrative units and ownerships, between levels of analyses, between different planning analyses, and between analyses and implementation.

Joyce et. al (1989) emphasize the importance of making advances in the area of ecological modeling when they say that:

> Ecological analysis developed to address planning requirements as implied in the Resource Planning Act (RPA) and the National Forest Management Act (NFMA) have suffered from the lack of underlying joint production theory, the difficulties in linking economic and ecological analysis, the spatial problems of quantifying "mobile" resources response to management activities, the problems in determining the cumulative effects of management actions, and in many cases, a lack of the necessary resource data. The RPA and NFMA analyses are: (1) complex because they are multi-resource, multi-disciplinary, and multi-level (i.e. span many spatial and temporal scales, and (2) expensive because of development costs, analytical and computational (implementation) costs and personnel time.

Hoekstra et al. 1989 call for research in the area of multilevel interactions because of present inefficiencies,

linkages between different agency activities eg.planning, budgeting and plan implementation and interactions of forest system lands with other lands (federal, state, or private).

Risk and Uncertainty

Hof (1988) stresses the need for studying risk and uncertainty in saying:

> The high priority areas for expansion include accounting for risk and uncertainty (as well as ecological discontinuities and irreversibility). Specific areas for research include investigating mathematical representation of risk-neutral and risk-averse optimization under conditions of yield risk and uncertainty, modeling of discontinuities with respect to fire, insect, and disease infestations, and other dramatic ecological changes, along with investigation of risk and uncertainty resulting from sampling and measurement of data that supports resource planning analysis (Hoekstra et al. 1989).

Kent (1989) offers comment on the need to incorporate ways of handling risk and uncertainty:

> The FORPLAN analysis currently being conducted can be characterized as an acre-by-acre approach since the optimal solution for the LP is comprised of an allocation of each acre on the forest to some management prescription (Mitchell and Kent 1987). Two problems with this approach are that it fails to deal effectively with uncertainty (Hof 1988, Kent 1980) and it fails to view forest management as an adaptive process. As Walters (1986) points out: we learn about the potential of natural populations to sustain harvesting mainly through experience with management itself, rather than through basic research or the development of general ecological theory.

Kent, Hof, and Joyce (1988) include closely related research questions which must be answered include:

- A more complete characterization of the agency's overall planning process needs to be developed.
- The role of forest planning, and the role of analysis must be clearly defined.
- Planning strategies must be identified. Should totally rational comprehensive or hierarchical approaches be used and what is the role of analysis in planning?
- The choice of analysis tools must then be considered and new systems must be developed or existing ones modified as appropriate.

They say that:

> Necessary linkages between systems must also be identified and developed. This work must take into consideration the need to better incorporate nontimber resources, spatial concerns, and uncertainty in planning analysis. Throughout all of these investigations, the need to make planning and analysis understandable to interested parties both in and outside the agency must be kept in mind. Necessary linkages between different levels of planning must be developed and at all times the underlying goal of improving management and decision making through planning must be kept in mind.

Kent, Hof, and Joyce (1988) also identify three applied research problems:

1) Critical data needs for planning and analysis must be identified and satisfied.
2) Our understanding both of how to implement plans and utilize the results of implementation to facilitate the next round of planning must be improved.
3) A better understanding of the implications of budget levels on planning must be developed.

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